Defining a consistent UT/LS O₃ field from the Aura data

Qi Tang and Michael Prather
Earth System Science Department, UC Irvine

plus the help and support of the Aura Science Team
Using Hindcast Validation
to Build Confidence in Projections

Michael Prather
Chris Holmes
Qi Tang*
Jordan Schnell

Earth System Science Department, UC Irvine
* now Cornell U.
Defining a consistent UT/LS O$_3$ field from the Aura data
(parable: five blind men and an elephant)

**OUR WORK**

UCI CTM running full chemistry at high resolution (1° x 1° x ~1 km x 30') with realistic meteorology from the ECMWF IFS (T159L4) for 2005-2006 provides a transfer standard for all "five" Aura L2 ozone measurements.

For example, the CTM is able to "see" the 4-D ozone fields with their high-frequency variability in the UT/LS and thus allows direct comparisons of HIRDLS and MLS L2 data, even though they are looking at different parts of the atmosphere.

A satellite simulator was developed for the UCI CTM: O$_3$ simulations are archived every 30 minutes along the Aura orbit; each orbital observation is interpolated between two of these results; the archived swath is wide enough to include the cross-track scan of OMI and the off-track viewing geometry of HIRDLS (outside the OMI swath); and thus each L2 measurement has a corresponding CTM O$_3$ profile.
Correlating tropospheric column ozone with tropopause folds: the Aura-OMI satellite data

Q. Tang and M. J. Prather

Atmos. Chem. Phys., 10, 9681–9688, 2010
www.atmos-chem-phys.net/10/9681/2010/
doi:10.5194/acp-10-9681-2010
10 Jun 2005  

**Tropospheric Column O₃**

3 Dec 2005 (25-hr of swaths)

(a) OMI

(b) a priori problem ~30S

(c) CTM
GLOBAL comparison for all OMI L2 data in 1°x1° grid, approx. 2x10^6 pts/month
Future methane, OH, and their uncertainties: parametric relations with emissions and climate change

Christopher D. Holmes

Michael Prather, Qi Tang, Mingquan Mu, Ivar Isaksen, Amund Sovde

Methane oxidation, UCI CTM 1997-2009

$\text{CH}_4 + \text{OH} \xrightarrow{k} \text{products}$

$10^{-6} \text{ kg m}^{-2} \text{ d}^{-1}$
Methane lifetime, UCI CTM

Methane loss in troposphere above 200 hPa
0.5% in UCI CTM
1.5% in GEOS-Chem (larger due to acetone?)
Interannual variability of CH$_4$ lifetime

- **UCI CTM**
- **1998**
- **2000**
- **2002**
- **2004**
- **2006**
- **2008**
- **2010**
- **water vapor +5%**
- **ENSO**
- **decline**

**Interannual variability (1σ) of CH$_4$ oxidation**

**Sensitivity tests**
- water vapor
- temperature
- cloud OD
- biomass burning
- lightning NOx
Factors affecting CH$_4$ lifetime

<table>
<thead>
<tr>
<th>Forcing</th>
<th>Forcing variability (%)</th>
<th>$\tau_{CH_4}$ Response (%)</th>
<th>Important for interannual variability?</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>0.25</td>
<td>UC-I CTM: -5.2, GEOS-Chem: -3.0*#</td>
<td>yes!</td>
</tr>
<tr>
<td>water vapor</td>
<td>3</td>
<td>UC-I CTM: -0.32, GEOS-Chem: -0.34</td>
<td>yes!</td>
</tr>
<tr>
<td>lightning-NOx</td>
<td>15</td>
<td>UC-I CTM: -0.14, GEOS-Chem: -0.23</td>
<td>yes!</td>
</tr>
<tr>
<td>biomass burning</td>
<td>30</td>
<td>UC-I CTM: +0.023, GEOS-Chem: +0.03#</td>
<td>yes!</td>
</tr>
<tr>
<td>OD (water cloud)</td>
<td>2</td>
<td>UC-I CTM: -0.025</td>
<td>no</td>
</tr>
<tr>
<td>OD (ice cloud)</td>
<td>2</td>
<td>UC-I CTM: +0.013</td>
<td>no</td>
</tr>
<tr>
<td>surface NOx</td>
<td>-</td>
<td>UC-I CTM: -0.15, GEOS-Chem: -0.23</td>
<td>yes, on decadal time scale</td>
</tr>
<tr>
<td>CH$_4$ feedback</td>
<td>-</td>
<td>UC-I CTM: +0.369, GEOS-Chem: +0.274</td>
<td></td>
</tr>
</tbody>
</table>

* 6.5% would be expected from k(OH+CH$_4$) alone

# preliminary value, based on < 2 years simulation
Parametric model evaluation

Parameters used:
1. Temperature  (tropics, up to 400hPa)
2. Water vapor  (tropics)
3. Lightning NOx
4. Biomass burning
Model intercomparison

Similar variability in many models... even with varying biogenic and anthropogenic emissions, so... the same parameters likely control OH in other models.

References:
MCF constraint (Montzka et al. 2011)
ECHAM5 (Montzka et al. 2011)
UCI CTM/xRCP (this work)
GC/GEOS-5/xRCP (this work)
GC/GEOS-5 (courtesy M. Mu)
GC/MERRA (courtesy M. Mu)
Tropospheric OH in 2050

Example: RCP8.5

<table>
<thead>
<tr>
<th>Forcing</th>
<th>Forcing Change (2050-2000)</th>
<th>Reference</th>
<th>$\Delta \tau_{\text{CH}_4}$ (2050-2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>+1.5 ± 0.5K</td>
<td>IPCC AR4 (A1B)</td>
<td>-2.7 ± 1.4%</td>
</tr>
<tr>
<td>water vapor</td>
<td>+11 ± 3.5%</td>
<td>from temperature</td>
<td>-3.6 ± 1.2%</td>
</tr>
<tr>
<td>lightning NOx</td>
<td>0 ± 20%</td>
<td>speculative</td>
<td>0.0 ± 4%</td>
</tr>
<tr>
<td>biomass burning</td>
<td>-15%</td>
<td>RCP8.5</td>
<td>+0.35 ± 0.17%</td>
</tr>
<tr>
<td>anthro NOx</td>
<td>-19%</td>
<td>RCP8.5</td>
<td>+3.6 ± 0.8%</td>
</tr>
<tr>
<td>anthro CO</td>
<td>-12%</td>
<td>RCP8.5</td>
<td>-1.4%</td>
</tr>
<tr>
<td>anthro VOC</td>
<td>-2%</td>
<td>RCP8.5</td>
<td>-0.1%</td>
</tr>
<tr>
<td>CH$_4$ abundance</td>
<td>+56%</td>
<td>RCP8.5</td>
<td>+12 ± 1.2%</td>
</tr>
<tr>
<td>total (IPCC TAR)</td>
<td></td>
<td></td>
<td>+14%</td>
</tr>
<tr>
<td>total (this work)</td>
<td></td>
<td></td>
<td>+8.2 ± 4.6%</td>
</tr>
</tbody>
</table>

$^a$ Calculated with IPCC TAR sensitivity, which neglects uncertainty.

Large difference from TAR projection

ACCMIp: +4.7 ± 4.8% (6-model ensemble)

neglects uncertainty in projecting CH$_4$ to 2050
Diagnosing and Hindcasting Major Ozone Pollution Episodes
2005-2006

Jordan Schnell, Chris Holmes, Michael Prather